SPRING, CAVE, AND STYGOFAUNA INVESTIGATIONS AT WESTCAVE PRESERVE, TRAVIS COUNTY, TEXAS

Jessica Gordon in the entrance to Crystal Cave.

Prepared for
Westcave Preserve
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Abstract

This report details an assessment of springs and other karst features and their associated fauna conducted July through September 2020 at Westcave Preserve in accordance with the stewardship and research goals specified by the Balcones Canyonlands Conservation Plan. Researchers conducted a systematic search effort to identify, characterize, and map spring orifices and caves. Spring areas were searched for fauna, including invertebrates and neotenic *Eurycea* salamanders via visual searches of surface and subsurface habitat, grab sampling, and trapping. Researchers documented 19 springs and 4 caves. No *Eurycea* salamanders were found; however, further search is warranted. Multiple new records of groundwater invertebrates were obtained that await further taxonomic scrutiny.

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Introduction

Westcave Preserve, located in Round Mountain, Travis County, is a 76-acre property owned by the Lower Colorado River Authority (LCRA) and operated by the non-profit Westcave Outdoor Discovery Center (Figure 1). A portion of Westcave Preserve, 25.796 acres, is a tract of the Pedernales River macrosite of the Balcones Canyonlands Preserve.

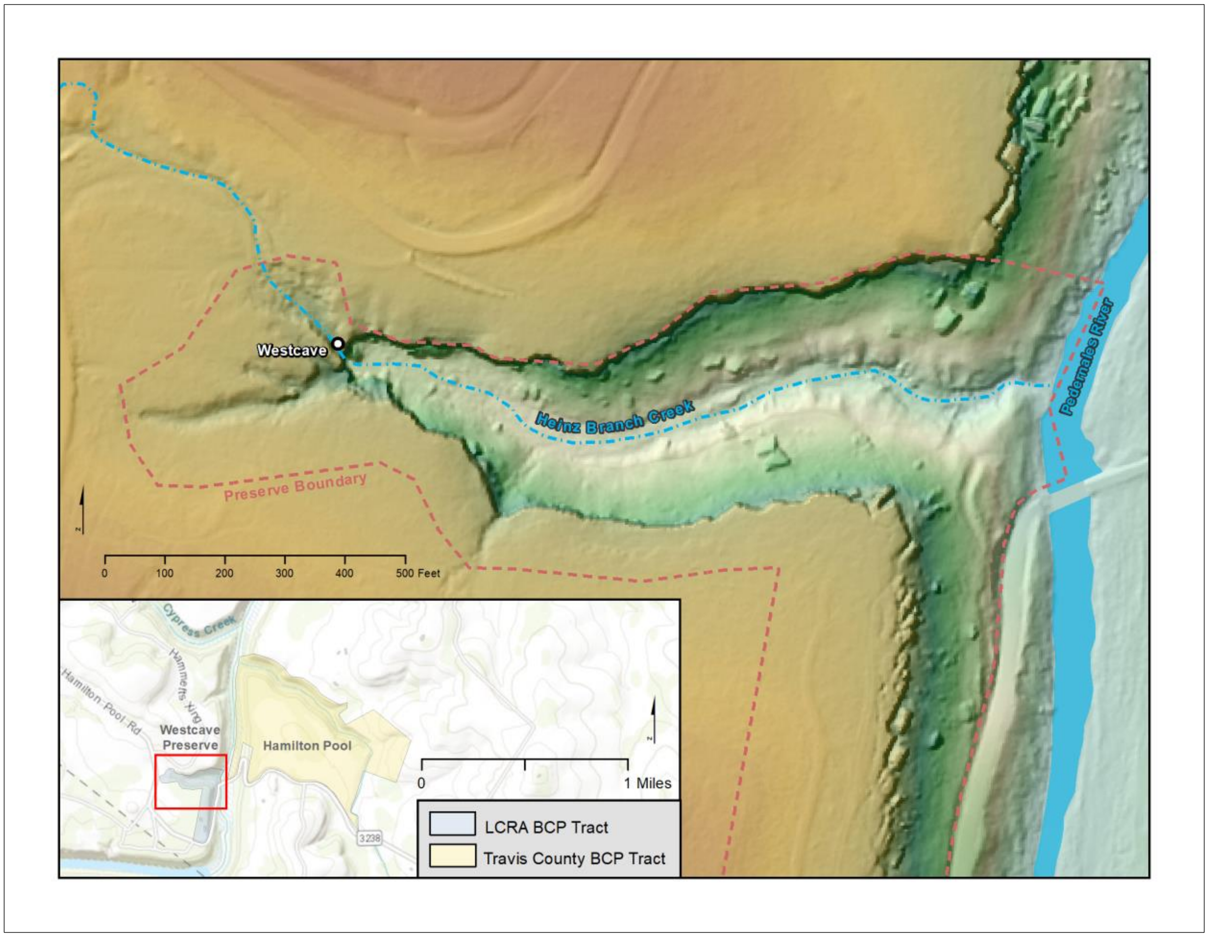

Figure 1. Project area showing Westcave Preserve, Round Mountain, Texas.

The Balcones Canyonlands Preserve (BCP) is a regional system of preserve tracts created for the protection of federally listed species and species of concern as specified by the Balcones Canyonlands Conservation Plan (BCCP). The BCCP is a regional 10(a)(1)(B) permit jointly issued to the City of Austin and Travis County by the U.S. Fish and Wildlife Service (USFWS) under the endangered species act. The regional permit addresses the stewardship of habitat for the permanent protection of eight federally listed endangered species (two songbirds and six invertebrates) and twenty-seven species of concern (two plants and twenty-five invertebrates). Should the species of concern become federally listed, no additional mitigation would be required by the permittees with the full implementation of all BCCP protections (BCP 2007, USFWS 1996).

The Balcones Canyonlands Preserve is located in Western Travis County on the eastern edge of the Edwards Plateau ecoregion. This area comprises part of the Balcones Canyonlands, characterized by steep streams and canyons deeply dissecting the Balcones Escarpment. The karstic limestone found here is highly fractured and pocked with numerous solution cavities and springs. These subterranean features and spring-fed drainages support unique ecological niches and a high degree of endemism (BCP 2007).

Balcones Canyonland Conservation Plan spring management obligations include identifying spring locations and monitoring for populations of aquatic target species. These management obligations include research goals that specify improving understanding of the ecology of preserve species and aquatic and subterranean environments. Those topics that contribute to management practices and permanent protection for listed species and species of concern are emphasized. The BCCP cites a lack of information regarding karst species and karst habitat management and specifically encourages research regarding aquatic life within the aquifer (BCP 2007).

Spring outflows provide access points or "windows" into aquatic subterranean ecosystems (Malard *et al.* 2002). The animals that occur in subsurface water are referred to as stygofauna. This report addresses the two categories of stygofauna found on the Balcones Canyonlands Preserve: the stygophiles that exploit aquatic subsurface environments for some portion of their life cycle, and the stygobites that complete their entire life cycle in subsurface waters (Malard *et al.* 2002).

Among the twenty-seven species of concern protected under the BCCP, three are stygobitic: the flatworm *Sphalloplana mohri*, the ostracod *Candona sp. nr. stagnalis*, and the isopod *Caecidotea reddelli*. Further, the BCCP identifies additional species of concern (BCP 2007). Of these are two stygobitic invertebrates: the amphipods *Stygobromus russelli* and *Stygobromus bifurcatus*. Both amphipods have a conservation status of vulnerable (Hutchins 2017), and *S. russelli* is a critically imperiled state species of greatest conservation need (TPWD 2012). The stygophilic "Pedernales Springs" salamander is not listed as a species of concern by the 1996-issued BCCP permit; however, the BCCP does list this species as an additional species of concern and indicates that *Eurycea* salamanders may deserve further scrutiny throughout the term of the permit (BCP 2007). Westcave Preserve is within the known range of the "Pedernales Springs" salamander, an undescribed neotenic

Eurycea species (*Eurycea* sp. 1) occurring in springs along the lower Pedernales River in Blanco, Travis, and Hays Counties (Devitt *et al*. 2019). NatureServe rankings indicate this salamander will be listed as critically imperiled once described (NatureServe 2020). Table 1 and Table 2 summarize the conservation status of the above stygofauna of the BCCP.

TABLE 1. The stygofauna protected under the BCCP along with their most recently assessed conservation status[1]. These species may merit federal listing if the BCP does not adequately protect their habitat[2].

Common name	Scientific Name	Conservation Status	Federal Status	State Species of Greatest Conservation Need
Flatworm	*Sphalloplana mohri*	Vulnerable		
Ostracod	*Candona sp. nr. stagnalis*			
Isopod	*Caecidotea reddelli*	Apparently secure		

[1] Hutchins, Benjamin 2017. The conservation status of Texas groundwater invertebrates. Biodiversity and Conservation. 10.1007/s10531-017-1447-0.
[2] Balcones Canyonlands Preserve 2007a. Balcones Canyonlands Preserve Land Management Plan, Tier I, Balcones Canyonlands Preserve Overview, Austin, Texas.

TABLE 2. The stygofauna the BCCP names as additional species of concern along with their most recently assessed conservation status[1].

Common name	Scientific Name	Conservation Status	Federal Status	State Species of Greatest Conservation Need
"Pedernales Springs" salamander	*Eurycea sp. 1*			
Bifurcated cave amphipod	*Stygobromus bifurcatus*	Vulnerable		
amphipod	*Stygobromus russelli*	Vulnerable		Critically Imperiled

[1] Hutchins, Benjamin 2017. The conservation status of Texas groundwater invertebrates. Biodiversity and Conservation. 10.1007/s10531-017-1447-0.

This technical report details an assessment of springs, caves, and their associated fauna at Westcave Preserve. This effort is in collaboration between Crystal Datri of Wren Daytree LLC (Wren Daytree) Peter Sprouse of Zara Environmental LLC (Zara), Jessica Gordon with the Texas Speleological Association, Dr. Benjamin Hutchins with the Edwards Aquifer Research and Data Center (EARDC), and the City of Austin (COA) Wildland Conservation Division. Wren Daytree LLC is currently conducting a spring and spring faunal assessment on the Balcones Canyonlands Preserve (BCP) under the direction of Dr. Nico Hauwert and in accordance with the stewardship and research goals specified by the Balcones Canyonlands Conservation Plan. The collaboration at Westcave Preserve is an extension of that effort. Please see the concurrent "2020 Summary of City of Austin Spring Management Activities on the Balcones Canyonlands Preserve" for BCP spring assessment work outside of Westcave Preserve.

Methods

Site visits were conducted 7 July; 7, 21, and 25 August; and 8 September 2020.

Identifying Spring Locations

Surveyors searched for karst features[1], including springs[2] and caves[3], evaluating those features as encountered. Search areas include: the stream run and tributaries of Heinz Branch immediately upstream of the Westcave grotto (previously known as Hammett's Cave), a minor pool inside Westcave, and the north and south canyon walls from Westcave to the confluence with the Pedernales River (Figures 1 and 2). Spring locations were documented when water issuing from an orifice[4] was observed. Seeps were documented where there was not an obvious orifice of flowing water, but indications of diffuse seepage. Positions of all features were documented with a commercial handheld Global Positioning System (GPS) receiver and checked with field maps based on digital imagery. The locations of all features were mapped using ArcGIS software.

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[1] *Karst feature:* a geologic feature formed by the solution of limestone. The term karst feature encompasses caves, sinkholes, fractures, springs and seeps, soil pipes, and solution cavities.

[2] *Spring:* ecosystem where groundwater reaches the Earth's surface either at or near the land-atmosphere interface or the land-water interface (Springer and Lawrence 2009). Seeps are small springs where discharge is immeasurably diffuse (Stevens *et al.* 2016).

[3] *Cave:* a naturally occurring feature in bedrock of a humanly enterable size, at least 5 meters in length or depth, in which no dimension of the entrance exceeds that of the cavity (Texas Speleological Survey).

[4] *Orifice:* the source of the spring or its point of emergence (Springer and Lawrence 2009).

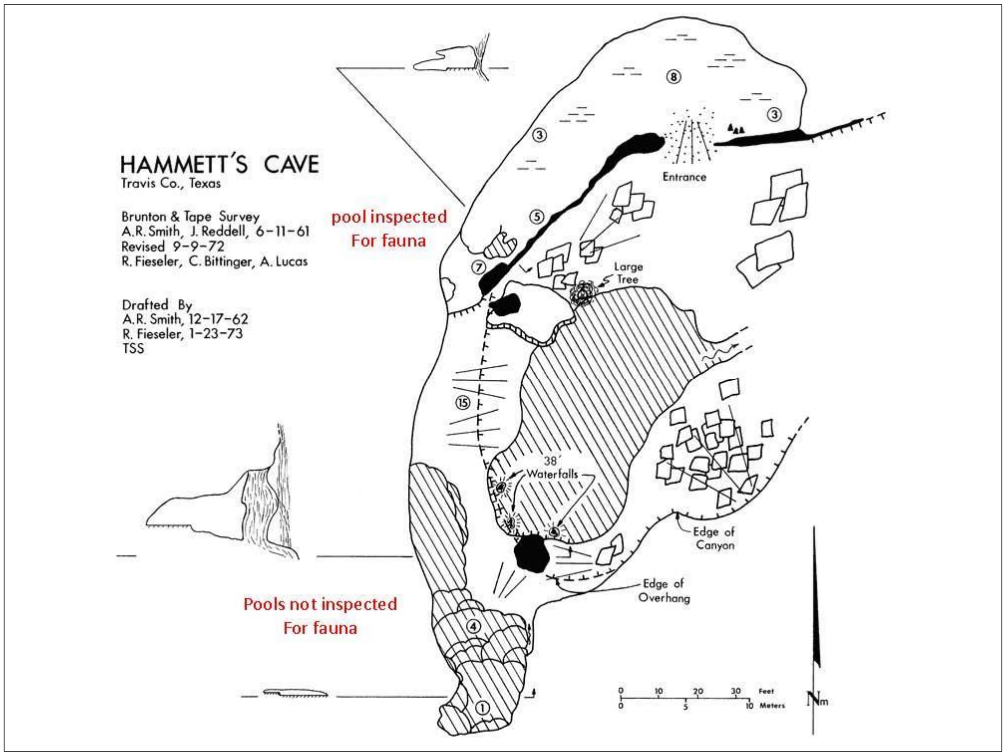

Figure 2. The areas searched in the previously surveyed Hammett's Cave, also known as Westcave.

Characterizing Spring Locations

Researchers focused on documenting characteristics in the immediate vicinity of spring orifices; however, in some cases, spring-run habitat deemed suitable for stygofauna was additionally described. The following characteristics were recorded when possible: size and description of orifice, photographs, water depth, substrate composition, water temperature, ambient temperature, some description of water quantity, and notable flora and fauna. Water temperature was measured as far into the spring orifice as a handheld probe thermometer (Reotemp K79-7) could reach. All feature locations were transmitted to the Texas Speleological Survey and the City of Austin Wildland Conservation Division.

Stygofauna

Researchers searched for salamanders and invertebrate stygofauna via visual searches of surface and subsurface habitat, grab sampling, and trapping (mop heads and bottle traps as appropriate). Visual searches consisted of removing and replacing cover objects such as rocks and leaf litter within the wetted perimeter in the immediate vicinity of the spring orifice where water accumulated enough to provide useable habitat, such as pools, streams, or within surveyable portions of caves. In some cases, search surface area and time were recorded. Submerged spring orifices can be difficult to discern. Further, other *Eurycea* salamander species are known to range widely (500m+) in spring-influenced stream habitats (Bendik et al. 2016). While traversing stream runs in search of spring locations, researchers frequently stopped to informally search what they evaluated as suitable habitat using their best judgement.

Specimen Collection and Curation

Invertebrate stygofauna were collected and fixated in 95% ethyl alcohol. Samples were sorted and assigned specimen numbers at Zara Environmental LLC. Samples were then sent to the Edwards Aquifer Research and Data Center at Texas State University (crustaceans, aquatic beetles, and snails) and the Texas Biodiveristy Collections, University of Texas at Austin (other invertebrates), where they await further taxonomic scrutiny and curation. Snail specimens were forwarded to Kathryn Perez (assistant professor of biology at University of Texas Rio Grande Valle at Edinburg), who identified the aquatic snails to species (Kathryn Perez, pers com).

Environmental DNA

Water samples for environmental DNA study were collected from pools inside of Crystal Cave, Geo-Wonder Cave, and Westcave. These samples were collected on behalf of and given to Ruben Tovar at the University of Texas at Austin.

Results

Identifying and Characterizing Undocumented Springs

24 features were documented: 19 springs and 4 caves. These feature locations are depicted in Figure 3 and in landscape view in Appendix A and described below. Feature coordinates can be found in Appendix B.

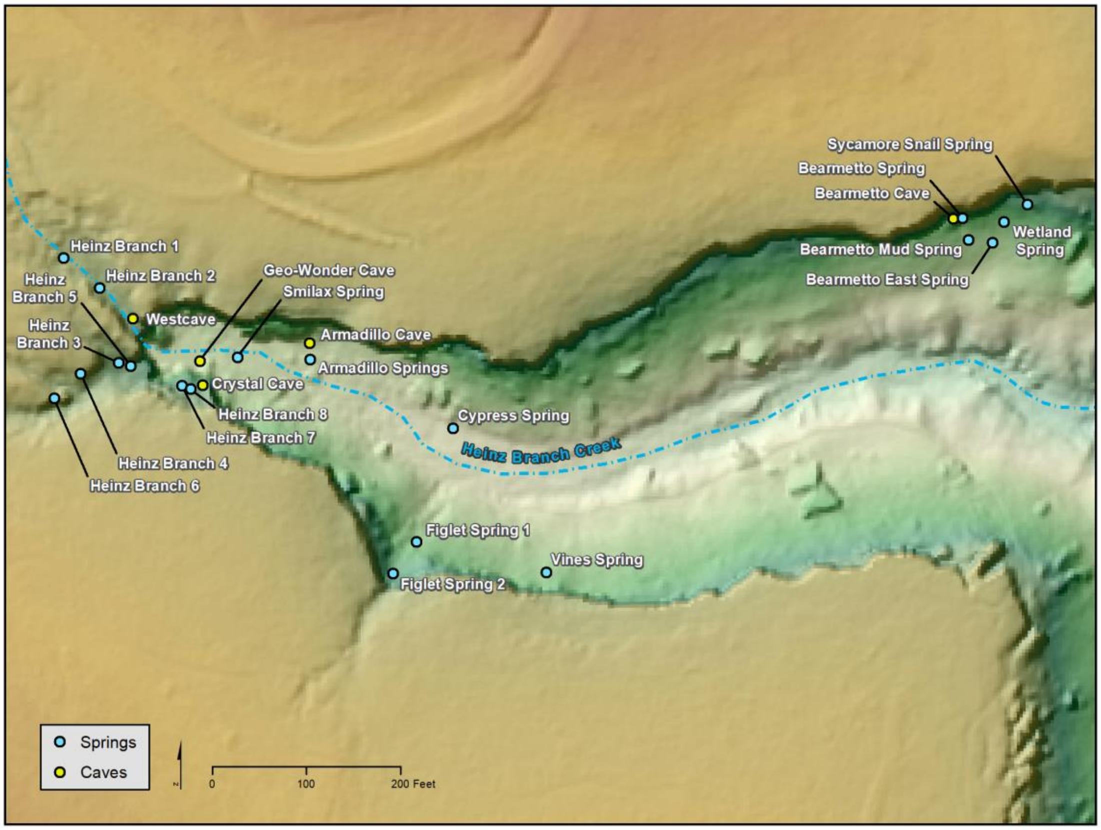

Figure 3. Features documented at Westcave Preserve. Map by Colin Strickland.

Upper Heinz Branch

These features are located upstream of the canyon where the main stem of Heinz Branch is joined by a tributary from the south, to descend over Westcave.

Heinz Branch Spring no. 1 is the uppermost spring in the main stem of Heinz Branch (Figure 4). Flows here are barely discernable, emanating among bunch grasses, and traveling across bedrock. These intermittent puddles gain flow as they continue downstream, joining the flows of Heinz Branch no. 2 (Figure 5), where the vegetation becomes more spring-influenced. The orifices of Heinz Branch no. 2 are in the southern bank of a pool, among shield and maiden hair ferns. These flows continue to gain, ultimately pouring off above Westcave just past a small cypress tree (Figure 6). Bottle traps and sediment and aquatic vegetation grab samples were examined for groundwater fauna. Eyed amphipods (most likely *Hyalella* sp.), ostracods, planaria, and a partial shell of a domed cavesnail (*Phreatodrobia nugax*) were collected from Heinz Branch no. 2.

Figure 4. Heinz Branch Spring no. 1

Figure 5. Peter Sprouse deploys a bottle trap in Heinz Branch Spring no. 2. (photo left, looking upstream). Looking south at the orifices of Heinz Branch Spring no. 2 (photo right).

Figure 6. Looking downstream from the pool at Heinz Branch Spring no. 2. The pour-off above the grotto is just beyond the cypress tree.

Heinz Branch Spring no. 6 is the uppermost spring found in the southern tributary of Heinz Branch. Flow increases from spring no's 5, 4, and 3 continuing downstream, among tufa deposits, maiden hair ferns, and cypress roots, before pouring off above Westcave. No. 3 is on the southern wall of this tributary, near a spicebush and a dead tree (Figure 7).

Figure 7. Peter Sprouse searches for invertebrates at Heinz Branch Spring no. 3.

Following the southern wall towards the east leads to Heinz Branch springs no.'s 7 and 8, and Crystal Cave.

Heinz Branch Spring no. 7 is comprised of two orifices (Figure 8). These flows cascade down a tufa bank in tiny pools of organics where invertebrates find refuge. No. 7's springs are approximately 3 meters northwest of Heinz Branch Spring no. 8 (Figure 9).

Heinz Branch Spring no. 8 is located between no. 7 and Crystal Cave. Water emanates from a crack in the cliff wall, dispersing across a tufa bank. Some of these flows travel eastward (to the left, when facing the spring) towards a crack in front of Crystal Cave (Figure 10). Those flows travel west (to the right, when facing the spring), joining those flows from no. 7 in a short stream run of broken tufa sheeting and leaf litter. There are multiple spice bushes in the area as well as a large sycamore tree which is viewable down below in the grotto area as a point of reference. It appears that the combined flows from no. 7 and no. 8 continue down to Geo-Wonder Cave.


Figure 8. The two orifices at Heinz Branch no. 7.


Figure 9. The orifice at Heinz Branch no. 8.

Figure 10. The Heinz Branch no. 8 orifice is shown at the top. Crystal Cave is on the left. The flowpath from no. 8 to the crack in front of Crystal Cave is highlighted in red.

Amphipods (eyed), coleoptera (a riffle beetle), a stygobitic isopod (*Lirceolus* sp., Figure 11 left), domed cavesnails (*Phreatodrobia nugax*, Figure 11 right), and two small snails that were either domed cavesnails (*Phreatodrobia nugax*) or flattened cavesnails (*Phreatodrobia micra*) were collected from mop material in Heinz Branch no. 7. Amphipods (eyed), copepods, and ostracods, were collected from mop material in Heinz Branch Spring no. 8.

Figure 11. Stygobitic isopod (*Lirceolus* sp.) (photo left) and domed cavesnail (*Phreatodrobia nugax*) (photo right) collected from Heinz Branch Spring no. 7.

Crystal Cave

Crystal Cave is located in the south side of the canyon, east of Heinz Branch no. 8. The cliff-side entrance to Crystal Cave opens into a sloping passage with columns and stalagmites (Figure 12). To the left (east) of the cave entrance, the cliff overhang continues with cave-like formations. Crystal Cave is approximately 10 meters long. The passage opens into a flowstone-floored chamber leading to a pool of clear water approximately 5 meters long (Figure 13). Eyeless amphipods (*Stygobromus* sp., Figure 14 left), ostracods, copepods (Figure 14 right), and a stygobitic isopod (Asellidae sp.) were collected from bottle traps deployed in the pool. A map of Crystal Cave is shown in Figure 15.

Figure 12. Entrance to Crystal Cave.

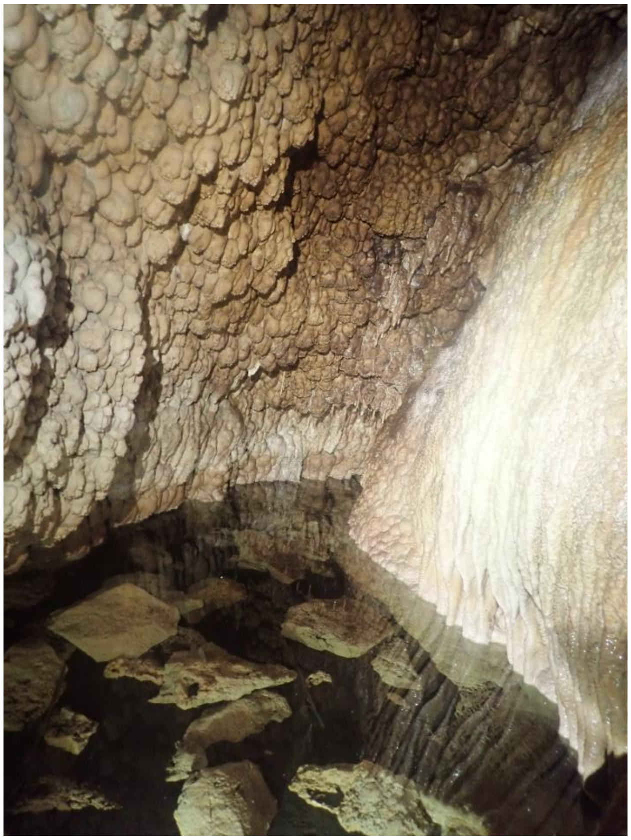

Figure 13. Pool inside Crystal Cave.

Figure 14. Eyeless amphipod (*Stygobromus* sp.) (photo left) and copepod (photo right) from Crystal Cave.

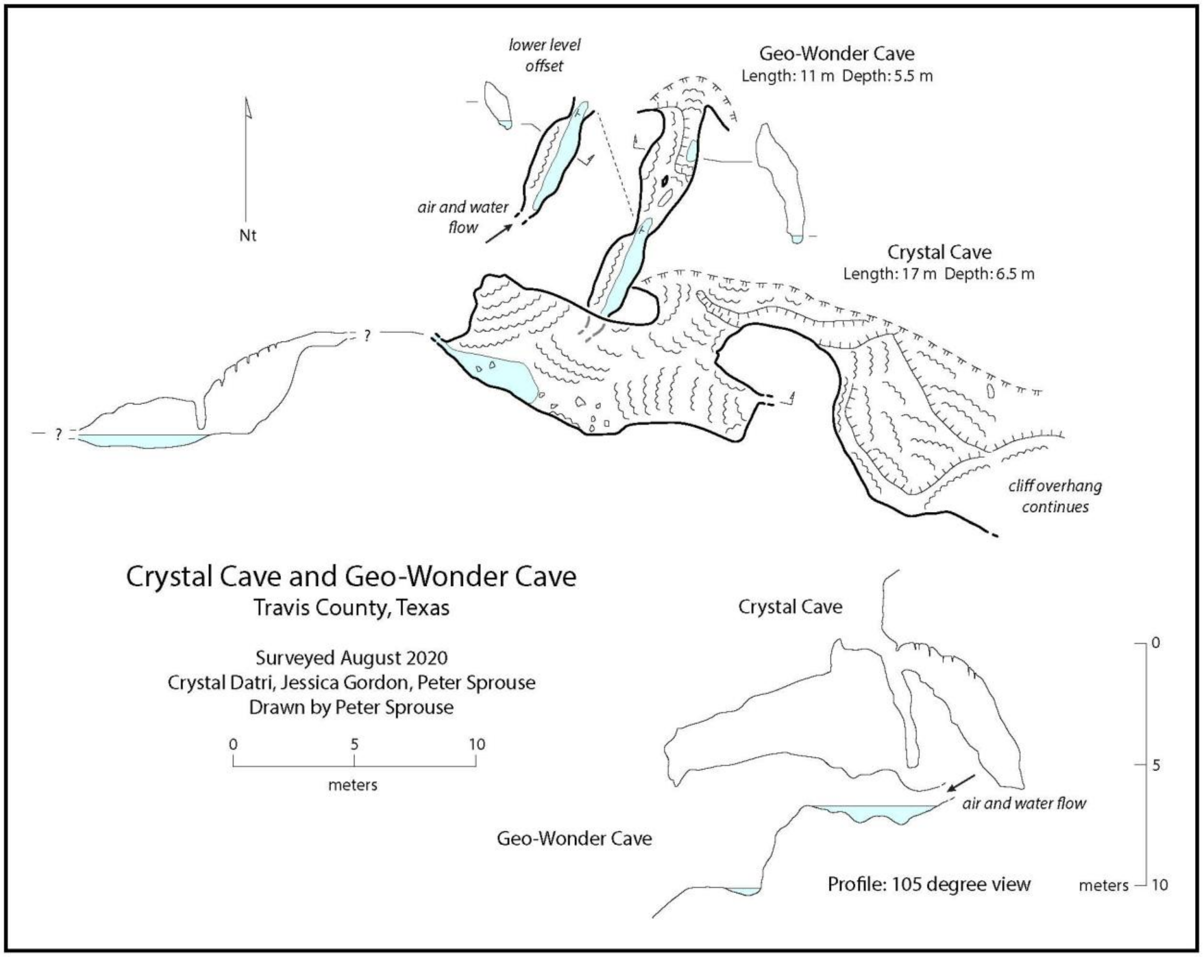

Figure 15. Map of Crystal and Geo-Wonder caves.

Geo-Wonder Cave

Geo-Wonder Cave is located lower down the canyon wall from Crystal Cave (Figure 15). The entrance is tall and narrow and seems to be developed along an enlarged fracture (Figure 16). A small stream flows into a pool just inside the entrance from a steep flowstone slope (Figure 17). At the top of this slope is another pool emanating from a passage that is too narrow to enter. This passage is directly below the pool in Crystal Cave, and seems likely to be related. Ostracods and copepods were collected from a bottle trap placed in the upper pool.


Figure 16. Entrance to Geo-Wonder Cave.

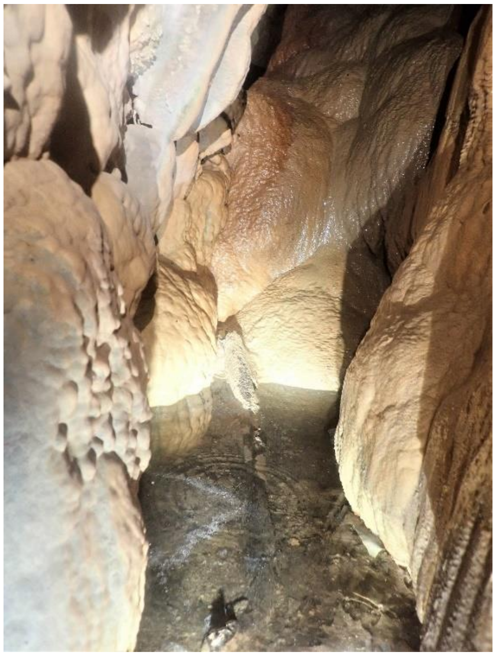
Figure 17. Pool inside entrance of Geo-Wonder Cave.

Smilax Spring

Smilax Spring is located slightly downstream of the Westcave grotto pool on the north bank of Heinz Branch (between the grotto pool and Armadillo Spring) next to a large cypress tree and several greenbriar vines (*Smilax* spp.) (Figure 18). Domed cavesnails (*Phreatodrobia nugax*) were collected in the sediment near the orifice of the spring.


Figure 18. Smilax Spring.

Armadillo Spring

This spring is located downstream of the grotto pool on the north bank of Heinz Branch. There are two main orifices issuing from a large tufa bank within 2 meters of each other: the eastern and the western. Each is a group of several small flows emanating from substrates comprised of calcified gravels, sands, and roots. Flows fan out toward cypress trees (Figure 19). Amphipods (eyed) and domed cavesnails (*Phreatodrobia nugax*) were collected from mop material in both orifices.

Figure 19. Armadillo Spring. The western orifices emanate near the spicebush shown in the top left of the photo.

Armadillo Cave

Armadillo Cave is located in the canyon wall above the spring of the same name. It is a through-trip crawlway that extends for 10 meters. It is formed within a travertine deposit and has many speleothems (Figure 20). The cave map is provided in Figure 21.

Figure 20. One of the entrances to Armadillo Cave (photo left). Speleothems inside Armadillo Cave (photo right).

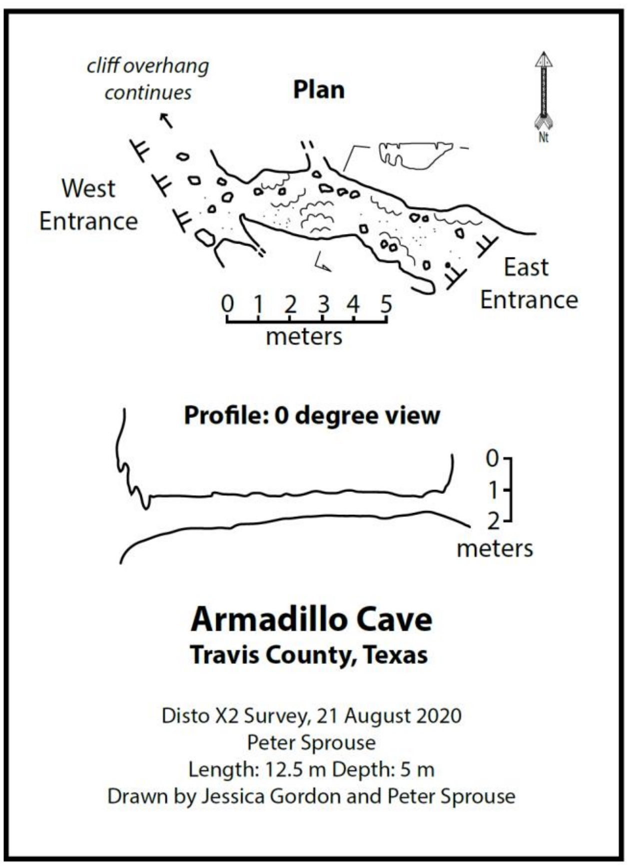

Figure 21. Map of Armadillo Cave.

Cypress Spring

This spring is east of Armadillo Spring, approximately 2 meters up the north creek bank from a large pool in Heinz Branch. Flows emanate from underneath and among the cracks of a large boulder, combining in shallow pools (1 cm) with some rock cover at the base of a cypress tree (Figure 22). Amphipods (eyed) and domed cavesnails (*Phreatodrobia nugax*) were collected from a mop trap in the main orifice.

Figure 22. Cypress Spring.

Figlet Springs

These springs are located downstream from the grotto pool, on the south side of Heinz Branch. Figlet no. 1 is east of Figlet no. 2. Multiple fig trees have invaded the wet habitat.

<u>Figlet Spring no. 1</u>

This spring emanates from the base of the cliff wall into a small pool of woody organic matter, silt, and coarse sands (Figure 23). It continues with an approximately 2-meter stream run of quality habitat for a number of spring associated invertebrates and potentially salamanders before dropping off a tufa bank, fanning out, and combining with flows from Figlet Spring no. 2. These flows continue downstream, crossing the JCW Canyon Trail and joining Heinz Branch. Here at the crossing, changes in flow throughout the day due to evapotranspiration can be observed. Stygobitic isopods (*Caecidotea* sp., Figure 23 right), and *Lirceolus* sp.), copepods, planaria, and domed cavesnails (*Phreatodrobia nugax*) were collected from mop material from Figlet Spring no. 1. A portion of the *Phreatodrobia* snails that were collected were so small that it is unclear if they are domed cavesnails (*Phreatodrobia nugax*) or flattened cavesnails (*Phreatodrobia micra*), but they seemed closer to *P. nugax* (Kathryn Perez per com).

Figure 23. The orifice at Figlet Spring no. 1 (photo left) and a stygobitic isopod (*Caecidotea* sp.) collected from Figlet Spring no. 1 (photo right).

Figlet Spring no. 2

Tufa formation and an abundance of shield and maiden hair ferns cascade down the cliff wall from an apparent stream run cutting down from the top of the canyon. Figlet Spring no. 2 is comprised of multiple orifices among these formations, with flowing water, apparently gaining, observed downstream from a possible elm tree (Figure 24).

These flows combine with those from no. 1. It appears that flows could emanate from more sources between no.'s 1 and 2 in wetter times.

Figure 24. Figlet Spring no. 2.

Vines Spring

Vines Spring is located downstream from the Figlets, also on the south side of Heinz Branch. It emanates from a shallow shelter high-up along the cliff face among vines and flows over a large tufa formation covered in maiden hair ferns below. Only drips were observed here (Figure 25). Little Walnut Seep and Last Seep are small features in the vicinity of Vines Spring that are not depicted on the map. No flows or drips were discerned at these two sites during these field visits; however, it is possible above-ground habitat could be found here in wetter times.


Figure 25. The tufa formation at Vines Spring.

Bearmetto Springs Complex

A cave and high spring activity characterize this approximate 25 meters along the north canyon wall of Heinz Branch as it approaches the Pedernales River.

Bearmetto Cave

Bearmetto Cave is located on the canyon wall approximately 4.5 meters west of the spring of the same name. The cave is formed where a large boulder broke off from the cliff wall, blocking a long, overhung portion of the cliff face. Travertine filled up much of the space between the boulder and cliff wall, making a cave with two entrances (Figure 26). It is a dry crawlway of 12 meters with some stalactites and flowstone. A single cliff chirping frog was observed in the cave. It is named after the beargrass and palmetto that is found around the entrances. The cave map is provided in Figure 27.

Figure 26. Looking out of one of the entrances of Bearmetto Cave (photo left). Photo right shows one of the entrances of Bearmetto Cave with a portion of the apparent flow path from Bearmetto Spring in the right of the photo.

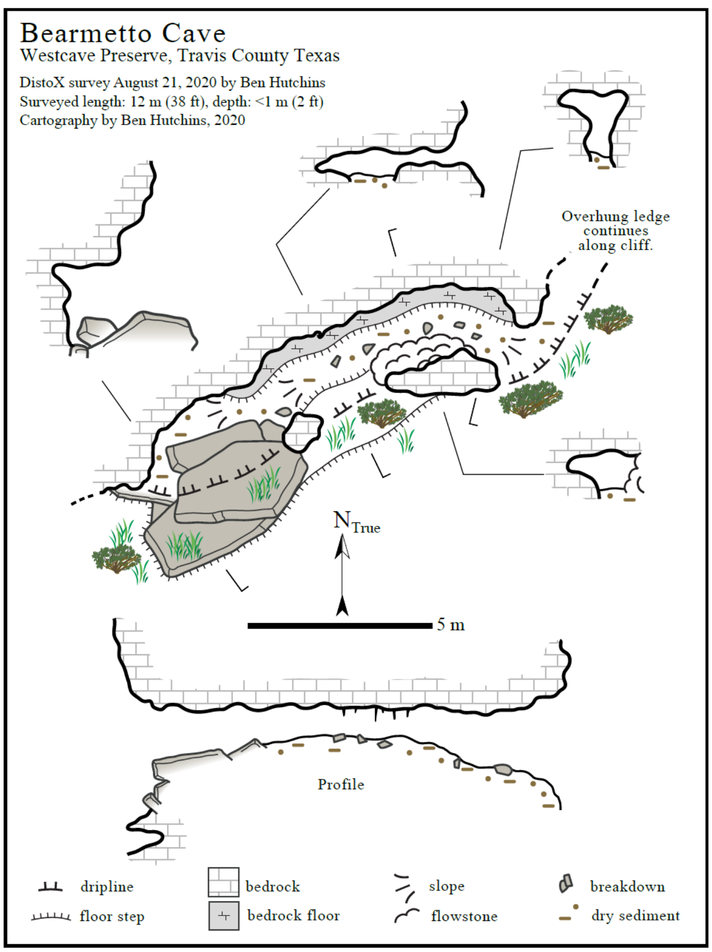

Figure 27. Map of Bearmetto Cave.

Bearmetto Spring

This spring is located approximately 4.5 meters east of the Bearmetto Cave entrance and approximately 3 meters north of a large sycamore tree. A spicebush is growing out of its supposed orifice. Researchers observed moist tufa formation, mosses, and maiden hair ferns, but no discernable flows (Figure 28). It does appear that flows would emanate in wetter times. Water is likely buried in sediments and reemerging directly south at Bearmetto Mud Spring.

Figure 28. Bearmetto Spring.

Bearmetto Mud Spring

This flow appears to be a reemergence from sediments of Bearmetto Spring, approximately 9 meters to the north. A short stream emanates at a shallow (3 cm) puddle comprised of mud and organics, and continues approximately 8 meters south before sinking in rich sediments among turks cap and cardinal flowers (Figure 29). Few macroscopic invertebrates were observed in visual searches at this spring as compared to the other springs of Westcave Preserve. Isopods (eyed) (Figure 30) and domed cavesnails (*Phreatodrobia nugax*) were collected. Enough snails with tissue were collected for future DNA analyses (Kathryn Perez, pers com). A large sycamore grows between Bearmetto Mud Spring and Bearmetto Spring. There are brown maiden hair ferns and dry tufa formation below the sycamore, indicating that in wet times, flows continue between Bearmetto Spring and Bearmetto Mud Spring.

Figure 29. Bearmetto Mud Spring. The photo on the left is from 21 Aug 2020. The photo on the right is from 6 Sept 2020, following a significant rain event.

Figure 30. Eyed isopod from Bearmetto Mud Spring.

Bearmetto East Spring

This spring cluster is approximately 3 meters east of Bearmetto Spring. Multiple drips emanate from a tufa bank, congregating in shallow puddles of mud and organics among palmettos. Flows from these springs likely reemerge as dispersed flows to the south forming a wetland with cardinal flowers (Figure 31).

Figure 31. The base of the tufa formation at Bearmetto East (photo left). The wetland south of Bearmetto East (photo right).

Sycamore Snail Spring

A large sycamore grows here at the base of the cliff wall. There are shield ferns here, but approximately 50% of them were observed brown. Damp sediments, moss, and tufa formation occur here, indicating there are flows in wetter times (Figure 32).


Figure 32. Sycamore Snail Spring.

Stygofauna Specimen Collection and Curation

No *Eurcyea* salamanders were observed. A summary of collected and sorted invertebrate fauna with preliminary identification is provided in Appendix C.

Discussion and Recommendations

This effort resulted in the first known collection of groundwater fauna at Westcave Preserve, expanding our knowledge of the distributions of stygofauna. We report new occurrence records for eyed amphipods (likely *Hyallela* sp.), *Stygobromus* sp. amphipods (possibly *Stygobromus balconis*, *Stygobromus bifurcates*, *Stygobromus flagellates*, and/or *Stygobromus russelli*), copepods, *Caecidotea* sp. isopods (possibly *Caecidotea reddelli)*, *Lirceolus* sp., isopods (possibly *Lirceolus bisetus* or *Lirceolus hardeni*), an unidentified Asellid isopod, an eyed isopod, ostracods, domed cavesnails (*Phreatodrobia nugax*), a riffle beetle, and planaria.

Small *Phreatodrobia* snails were collected from two of the springs (Figlet Spring no. 1 and Heinz Branch Spring no. 7). It is unclear if they are domed cavesnails (*Phreatodrobia nugax*) or flattened cavesnails (*Phreatodrobia micra*). They have features typical of either species. The specimens collected from Figlet Spring no. 1 appear more likely to be *P. nugax* (Kathryn Perez, pers com). *Phreatodrobia nugax* and *P. micra* are both stygobites that are endemic to Texas. These species live in phreatic (water-saturated zone, below the water table) and hyporheic (mixing zone of shallow groundwater and surface water along streams) habitats (Alvear et al. 2020). *Phreatodrobia nugax* are characterized as vulnerable, and *P. micra* are characterized as threatened based on conservation status rankings assigned by Hutchins (2017).

Further specimen identification is needed to determine whether our samples include any of the species of concern protected under the BCCP (i.e. the ostracod *Candona* sp. nr. *stagnalis* or the isopod *Caecidotea reddelli*) or any of the species the BCCP identifies as additional species of concern (i.e. the amphipods *Stygobromus russelli* and *Stygobromus bifurcatus*) (BCP 2007).

Detection probabilities for *Eurycea* sp. 1 are low. The known range is currently limited to approximately ten sites. These salamanders are not consistently found at known locations, and when they are, it is in low numbers. It is not surprising that they have not been found at Westcave Preserve, and we recommend continuing to search for them.

We did not search the stream-run of Heinz Branch in the canyon (downstream from the Westcave grotto). There are deeper waters in the main stream that contain predatory fish and it is a large search area that may be less easy to search than shallow stream-runs in the immediate vicinity of spring orifices; however, the main stream should not be ruled out as a future search area.

The pool below Westcave could be surveyed for spring orifices and *Eurycea* habitat by divers. Drift nets could be placed over identified orifices and checked on subsequent visits.

In periods of higher flow, some identified springs may be ideal for drift-net trapping. These traps should be checked at least once per week for salamanders. In addition, drift nets have a lower sampling bias for groundwater invertebrates than bottle traps and mop material and could yield a greater diversity. Field visits occurred July through September, a period of low rainfall. In periods of higher flow, more spring sites and/or habitat could become available for searching.

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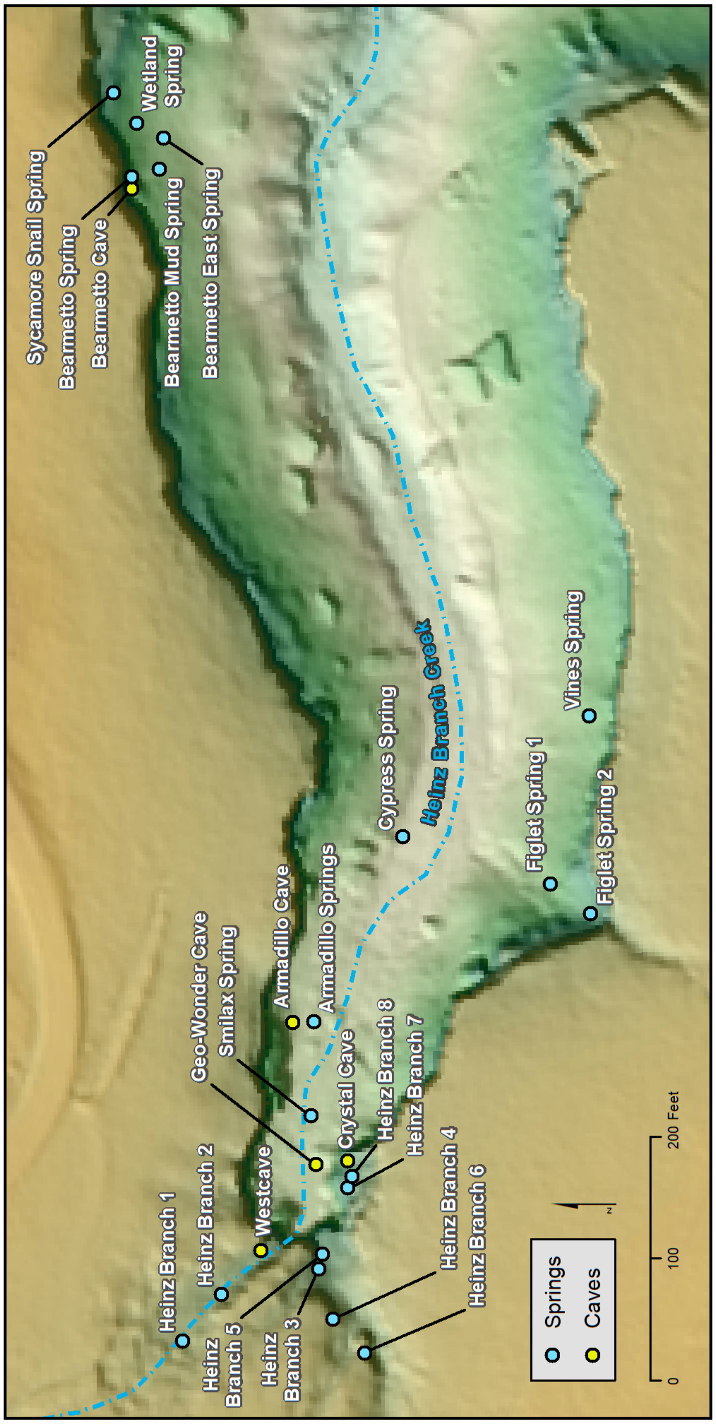
Appendix A. Feature Locations



Appendix B. Feature Coordinates

Karst Feature Name	Latitude	Longitude
Heinz Branch Spring no. 1	30.34087	-98.14323
Heinz Branch Spring no. 2	30.34078	-98.14311
Heinz Branch Spring no. 3	30.34056	-98.14305
Heinz Branch Spring no. 4	30.34053	-98.14318
Heinz Branch Spring no. 5	30.34055	-98.14301
Heinz Branch Spring no. 6	30.34046	-98.14327
Heinz Branch Spring no. 7	30.34049	-98.14284
Heinz Branch Spring no. 8	30.34048	-98.14281
Crystal Cave	30.340490	-98.14277
Geo-Wonder Cave	30.3405605	-98.1427763
Smilax Spring	30.34057	-98.14265
Armadillo Springs	30.340559	-98.142406
Armadillo Cave	30.3406071	-98.1424069
Cypress Spring	30.34035	-98.14193
Figlet Spring no. 1	30.34002	-98.14206
Figlet Springs no. 2	30.33993	-98.14214
Vines Spring	30.339924	-98.141625
Bearmetto Cave	30.3409335	-98.1402315
Bearmetto Mud Spring	30.34087	-98.14018
Bearmetto Spring	30.3409333	-98.1402003
Bearmetto East Spring	30.34086	-98.14010
Sycamore Snail Spring	30.34097	-98.13998
Wetland Spring	30.34092	-98.14006

Appendix C. Summary of Collections by Feature

Site	Date	Crustacea Amphipoda Eyed amphipods	Crustacea Amphipoda Crangonyctidae *Stygobromus* sp.	Crustacea Copepoda Copepods	Crustacea Isopoda Asselidae *Caecidotea sp.*	Crustacea Isopoda Asselidae Lirceolus sp.	Crustacea Isopoda Asselidae und.	Crustacea Isopoda Eyed isopods	Crustacea Ostracoda Ostracods	Mollusca Mesogastropoda Hydrobiidae Domed Cavesnail (*Phreatodrobia nugax*)	Mollusca Mesogastropoda Hydrobiidae Flattened Cavesnail (*Phreatodrobia micra*)	Coleoptera Elmidae Riffle beetle	Rhabditophora Tricladida Planariidae *Planaria* sp.
Armadillo Spring	Jul 10 2020	x											
Armadillo Spring	Aug 21 2020	x											
Armadillo Spring	Sep 15 2020	x								x			
Bearmetto Mud Spring	Sep 15 2020							x		x			
Crystal Cave	Jul 10 2020		x										
Crystal Cave	Aug 7 2020		x	x			x		x				
Crystal Cave	Aug 21 2020		x	x					x				
Crystal Cave	Sep 15 2020			x					x				
Cypress Spring	Aug 21 2020	x								x			
Cypress Spring	Sep 15 2020	x								x			
Figlet Spring no. 1	Aug 7 2020			x	x	x				x			x
Figlet Spring no. 1	Aug 21 2020									x	possible		
Figlet Spring no. 1	Sep 15 2020				x					x	possible		
Geo-Wonder Cave	Sep 15 2020			x					x				
Heinz Spring no. 2	Jul 10 2020									x			

Appendix C. Summary of Collections by Feature (continued)

Site	Date	Crustacea Amphipoda Eyed amphipods	Crustacea Amphipoda Crangonyctidae *Stygobromus* sp.	Crustacea Copepoda Copepods	Crustacea Isopoda Asselidae *Caecidotea sp.*	Crustacea Isopoda Asselidae Lirceolus sp.	Crustacea Isopoda Asselidae und.	Crustacea Isopoda Eyed isopods	Crustacea Ostracoda Ostracods	Mollusca Mesogastropoda Hydrobiidae Domed Cavesnail (*Phreatodrobia nugax*)	Mollusca Mesogastropoda Hydrobiidae Flattened Cavesnail (*Phreatodrobia micra*)	Coleoptera Elmidae Riffle beetle	Rhabditophora Tricladida Planariidae *Planaria* sp.
Heinz Spring no. 2	Aug 7 2020	x							x			?	x
Heinz Spring no. 7	Aug 7 2020	x				x				x	possible	x	
Heinz Spring no. 7	Aug 21 2020	x								x	possible		
Heinz Spring no. 7	Sep 15 2020	x				x							
Heinz Spring no. 8	Aug 7 2020	x							x				
Heinz Spring no. 8	Aug 21 2020	x											
Heinz Spring no. 8	Sep 15 2020	x		x					x				
Smilax Spring	Sep 15 2020									x			